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AIR FORCE SURVEYS IN GEOPHYSICS

No. 29

A NOTE ON HIGH LEVEL TURBULENCE ENCOUNTERED BY A GLIDER

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DECEMBER 1952

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Foreword

The Mountain Wave Project, sponsored jointly by the Geophysics Research Directorate of the Air Force Cambridge Research Center and the Office of Naval Research, and directed in the field by the former, has reached a point where preliminary results show significant features. Air Force Surveys In Geophysics No. 15, "Forecasting the Mountain Wave," dealt with the description and forecast aspects of the wave phenomenon; "Flying The Mountain Wave," in the November 1952 issue of Flying Safety magazine considered the phenomenon from the pilot's viewpoint.

This note, aimed at those interested in aircraft design, deals with turbulence conditions which were measured while investigating the wave, but which are not restricted to wave conditions. These measurements indicate the presence of gust velocities of such a magnitude as to be possibly dangerous in the operation of high speed aircraft at levels near 40,000 feet

A Note on High Level Turbulence Encountered by Glider

Research gliders exploring the so-called "Mountain Wave" over the Sierra Nevada occasionally encountered severe turbulence in a layer near the tropopause.

This note presents an observation to those interested in aircraft design which indicates the order of magnitude of gust velocities occurring near the 40,000 ft level.

The particulars are as follows:

Glider: Pratt-Reed (Research glider of the Mountain Wave Project)

Pilots: Edgar, Kuettner

Location: 50 miles south of Bishop, California

Altitude: 38,000 feet

Temperature: $-65^{\circ}C$

Measured accelerations: $\Delta n = +3g$, $-2.5g$

Indicated Speed: 60 knots

Time: 1600 PST, 18 December 1951 (0000Z, 19 December 1951)

These are first gusts encountered after smooth steady flight in the stationary lee wave of the Sierra Nevada. They were measured by an accelerometer and have consequently to be considered with reservation and in terms of magnitude only. The reduced gust velocities were derived from the well known equation for the effective gust velocity:

$$U_e = \frac{2\Delta n\,(W/A)}{\rho_0\, v_e \left(\frac{dC_L}{d\alpha}\right) K}$$

where Δn is the measured net acceleration, W/A the wing loading, ρ_0 the air density at the ground, v_e the indicated speed of the aircraft, C_L the lift coefficient, α the angle of attack, and K the alleviation factor.[1]

The values applied are:

$\Delta n = 3.0$	$v_e = 100$ ft/sec
$W/A = 5.8$ (lb/ft^2)	$\partial C_L/\partial \alpha = 5.2$
$\rho_0 = 2.3 \times 10^{-3}$ (slugs/ft^3)	$K = 0.8$

The aspect ratio of the glider is approximately 13.

The resulting effective or "sharp edge" gust velocity is 37 feet per second corresponding to a "true" gust velocity of over 70 feet per second at the flight level. Effective gust velocities estimated in the order of magnitude of 40 feet per second were encountered between 32,000 and 40,000 feet on other occasions.

The diagram (Fig. 1) is a plot of lapse-time pictures, taken from the instrument panel on this particular flight, indicating the difficulties of flying under such conditions. (The plotted values of rate of climb should not be interpreted in terms of accelerations since the time intervals between instantaneous readings are too long.) The variations of indicated speed after 1556 PST occurred despite our best attempts to keep a constant velocity (not constant altitude) for tracking purposes. They are partly due to very strong variations of the horizontal wind component.

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1. Donely, Philip, "Summary of Information Relating to Gust Loads on Airplanes," N.A.C.A. Report #997 (1950)

As the 300 millibar map (Fig. 2) shows, this flight was made near the center of a jetstream,* confirming the statements of other authors that jet-stream conditions are favorable for high level turbulence. (Under normal conditions, the high level airflow of the lee wave is extremely smooth.) Figure 2 shows the contours at 300 millibars as dashed lines and the isotachs (lines of constant wind speed) in solid lines. Lapse time pictures of the cloud formation indicate that the turbulence elements are not created by the mountain range but rather are disturbances traveling through the mountain wave in which the glider soars.

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* The double circle denotes the location of the flight.

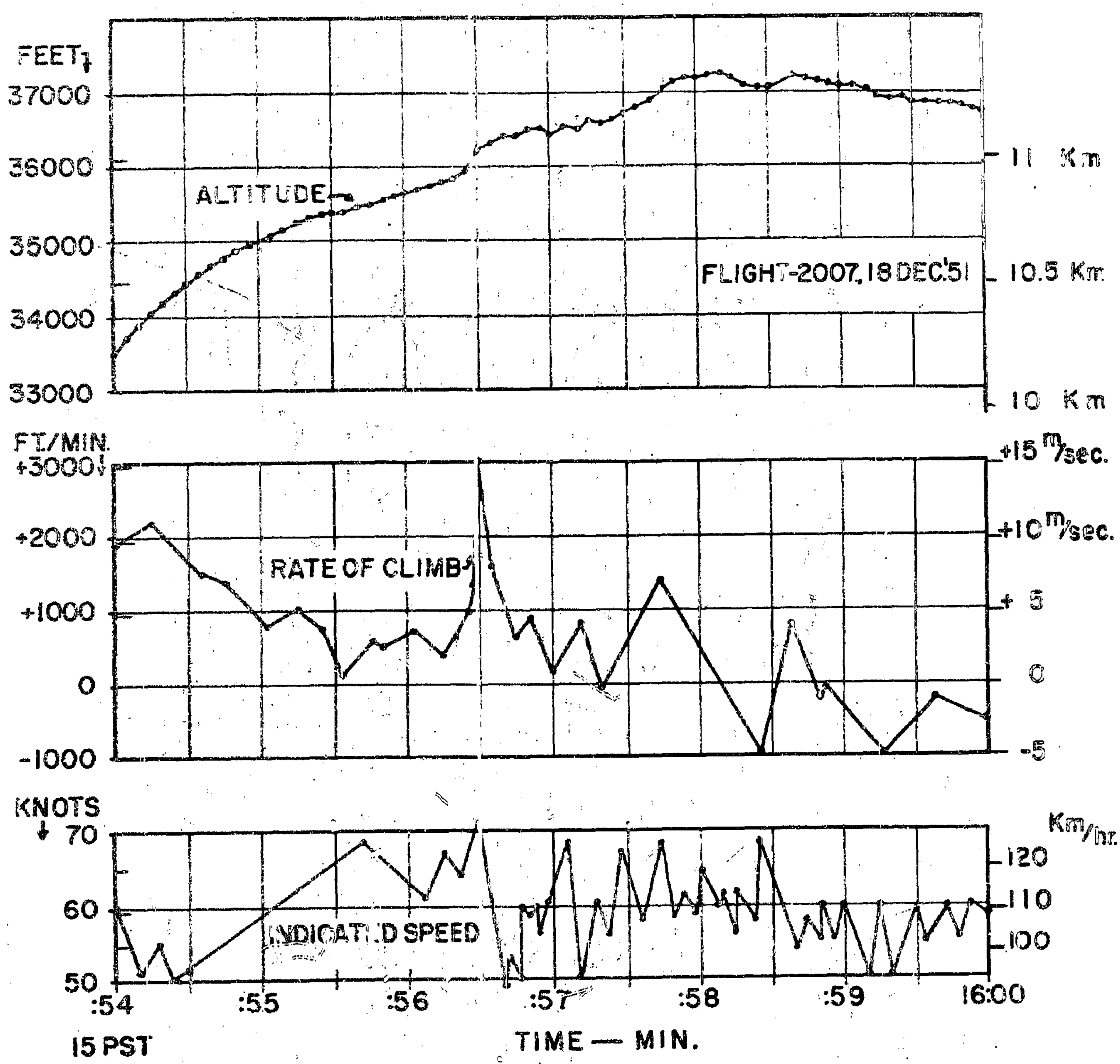
FEET
37000
36000
35000
34000
33000
ALTITUDE
FLIGHT-2007, 18 DEC.'51
11 Km
10.5 Km
10 Km
FT/MIN.
+3000
+2000
+1000
0
-1000
RATE OF CLIMB
+15 m/sec.
+10 m/sec.
+5
0
-5
KNOTS
70
60
50
INDICATED SPEED
Km/hr.
120
110
100
:54
:55
:56
:57
:58
:59
16:00
15 PST
TIME — MIN.

Fig. I

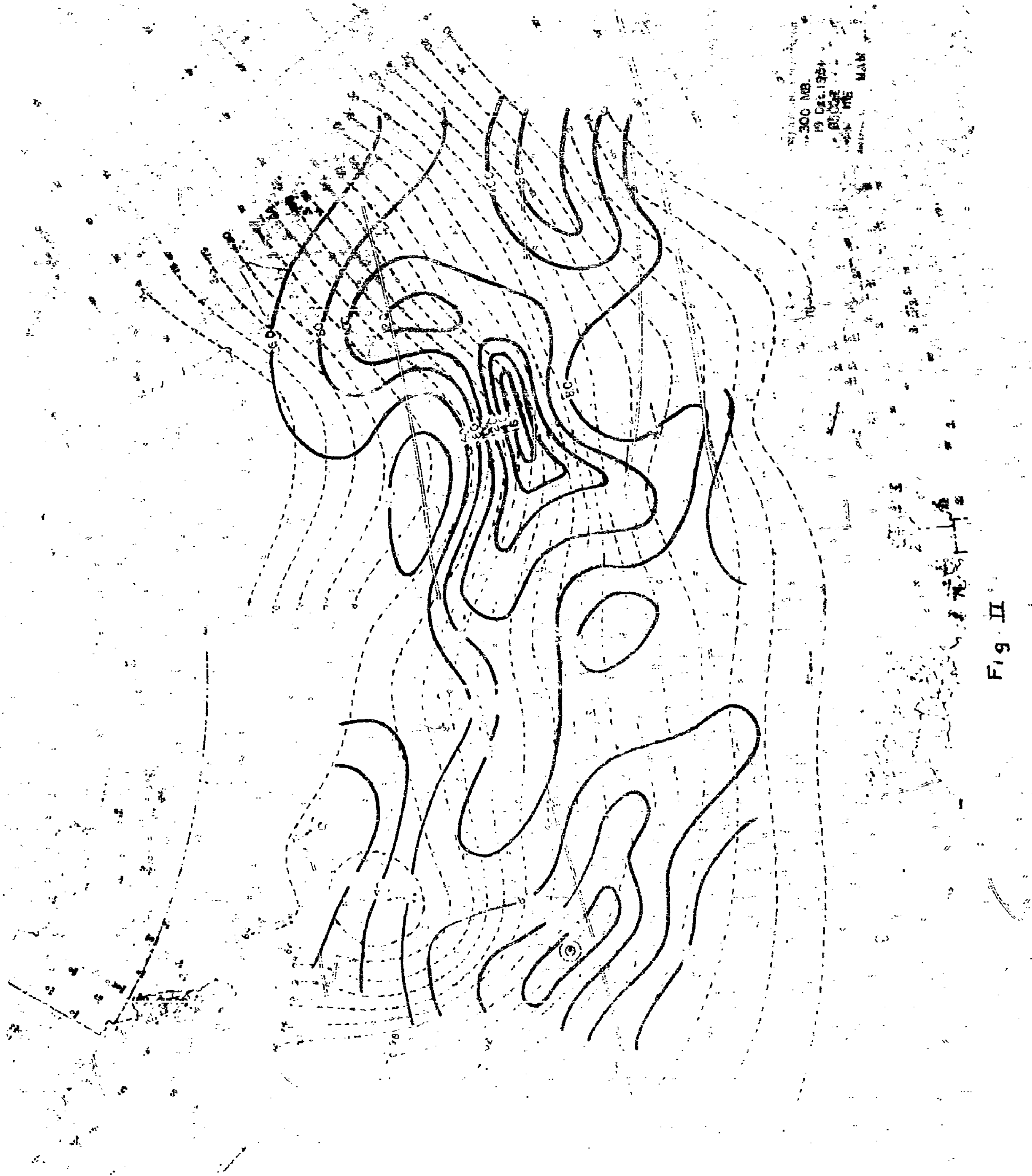

Fig. II

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List of Air Force Surveys In Geophysics

NUMBER	TITLE	AUTHOR	DATE	SEC. CLASS.
No. 1	CLASSIFIED			
No. 2	Methods of Weather Presentation for Air Defense Operations (UNCLASSIFIED TITLE)	William K. Widger, Jr., Capt., USAF	Jun 52	C
No. 3	CLASSIFIED			
No. 4	Final Report on Project 8-52M-1 Tropopause (UNCLASSIFIED TITLE)	S. Coroniti	Jul 52	S
No. 5	Infrared as a Means of Identification (UNCLASSIFIED TITLE)	Norman Oliver Joseph W. Chamberlain	Jul 52	S
No. 6	CLASSIFIED			
No. 7	CLASSIFIED			
No. 8	CLASSIFIED			
No. 9	CLASSIFIED			
No. 10	Soil Stabilization Report (UNCLASSIFIED TITLE)	Carl Molineaux	Sep 52	U
No. 11	Geodesy and Gravimetry, Preliminary Report (UNCLASSIFIED TITLE)	Ralph J. Ford Capt., USAF	Sep 52	S
No. 12	CLASSIFIED			
No. 13	CLASSIFIED			
No. 14	Forecasting Diffusion in the Lower Layers of the Atmosphere (UNCLASSIFIED TITLE)	Ben Davidson	Sep 52	R
No. 15	Forecasting the Mountain Wave (UNCLASSIFIED TITLE)	C. F. Jenkins	Sep 52	U
No. 16	CLASSIFIED			
No. 17	CLASSIFIED			
No. 18	CLASSIFIED			
No. 19	Contingency Method of Weather Forecasting (UNCLASSIFIED TITLE)	E. Wahl	Nov 52	U
No. 20	CLASSIFIED			
No. 21	Slant Visibility (UNCLASSIFIED TITLE)	R. Penndorf B. Goldberg D. Lufkin	Dec 52	U

NUMBER	TITLE	AUTHOR	DATE	SEC. CLASS.
No. 22	Geodesy and Gravimetry (UNCLASSIFIED TITLE)	Ralph J. Ford Capt., USAF	Dec 52	S
No. 23	Weather Effect on Radar (UNCLASSIFIED TITLE)	D. Atlas V. G. Plank W. H. Paulsen A. C. Chmela J. S. Marshall T. W. R. East K. L. S. Gunn	Dec 52	R
No. 24	A Survey of Available Information on Winds Above 30,000 Ft (UNCLASSIFIED TITLE)	C. F. Jenkins	Dec 52	U
No. 25	A Survey of Available Information on the Wind Fields Between the Surface and the Lower Stratosphere (UNCLASSIFIED TITLE)	William K. Widger Jr., Capt., USAF	Dec 52	U
No. 26	CLASSIFIED			
No. 27	CLASSIFIED			
No. 28	CLASSIFIED			